often be increased by elucidation of function under abnormal stresses. One general truth is emphasized in this work—that is, the very great factor of safety in many physiological processes.

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PERIPHERAL ARTERIAL EMBOLLECTOMY

BY

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The purpose of this paper is to review the literature on embol-ectomy, with special reference to the results; to stress the urgency of early diagnosis and prompt surgical treatment; and to describe a case in which a popliteal embol-ectomy was attended by success even though the time lapse between the occurrence of the embolism and the operation was greater than any other previously recorded.

Aetiology

The emboli we are concerned with are mainly derived from ante-mortem clot formed in the left side of the heart when stasis is present—chiefly in mitral stenosis. Occasionally the clot may be formed in the pulmonary or systemic veins; in the latter case the so-called “paradoxical embolus” occurs, being due to a persistent foramen ovale. But, nevertheless, cardiac dysfunction is the commonest cause: according to Danzis (1933) 60% of cases are due to cardiac disease, while of the 47 peripheral emboli recorded in Great Britain (in the available literature) 40 were of cardiac origin. Three of these occurred in thyrotoxic subjects with auricular fibrillation; the rest were in patients with mitral stenosis—the commonest single cause of embolism. Of the remaining 7, 6 were post-operative and one followed an accident which resulted in a fractured rib.

History of Arterial Embol-ectomy

Suabanejew, in 1895 (cited by Key, 1923), was the first to attempt “arteriotomy in order to remove a clot.” He was unsuccessful, as were the next 11 surgeons who followed his example. Among these were Moynihan (1903; not recorded until 1907) and Handley (1907), in England; Stewart (1905; cited by Allen, 1929), Murphy (1909), and Carrel (1909; cited by Allen, 1929), in America; and Lejars (1902; Allen, 1929), in France.

The first recorded success was described by Mosney and Dumont (1911), when Georges Labey removed an embolus from the bifurcation of the left femoral artery six hours after its lodgment. The patient, a man of 38, had mitral stenosis, and made a good recovery. In the same year Gordon-Watson, in England, attempted to remove a post-operative embolus under similar conditions. The leg, however, had to be amputated later, but the patient survived.

Einar Key, of Stockholm, who was responsible for the second reported successful case, introduced the operation in Scandinavia, after Carrel's experimental work had made arterial surgery a practical proposition (Allen, 1929). By 1923 Key was able to report 12 further successes, mainly by Scandinavian surgeons. In 1923 Holst (Danzis, 1933) reported the first success in America, while it was not until 1925 that Jefferson described the first success in England. In 1928 Pemberton collected 216 cases of embol-ectomy, of which only 20 had been done in Canada and America, while 145 of them were Scandinavian. Twenty cases had been reported in England by Riddell (1935), but by this time there were 382 cases on record for Scandinavia alone. It is evident that the Scandinavian surgeons had accepted embol-ectomy as a useful operation, while the general practitioners in that country were co-operating by sending

patients to hospital as soon as the diagnosis of peripheral embolism was suspected.

At the present time only 41 cases have been recorded in England; 47 emboli occurred in these, and embol-ectomy was carried out for 42 of them. The Registrar-General has, for the years 1941–3 alone, details of 34 deaths in which peripheral embolism played a part (personal communication), so there is no doubt that more than the 41 cases recorded have occurred in England since the time of Moynihan's first attempt.

Results

The main factor in the recovery rate of the limb in embol-ectomy is time—the time allowed to lapse between the lodgment of the embolus and the attempt to remove it. Pearse (1933) and Danzis (1933) have shown this to be true in their reviews of relatively large numbers of cases, which are expressed diagrammatically in Figs. 1 and 2.

The total successes reported in the past tend to give rather a gloomy impression (see Table), but on more careful examina-

Table showing Recovery Rates as found by Various Observers

Observer	Year	No. of Embol-ectomies	Successes	
			No.	%
Jefferson	1925	73	28	34.2
Danzis	1933	119	49	41.1
Pearse	1933	296	145	49.7
Key	1936	382	86	22.5
Hopkins	1945	42*	24	57.1

* This figure includes the 20 cases collected by Riddell (1935).

tion it becomes apparent that if *all* cases could be treated within 4 to 6 hours of the impaction of the embolus in the artery, then the total number of recoveries might be very much greater. Dickson Wright (1933) in a postgraduate lecture stated that there is a 50% chance of recovery after embol-ectomy. Without operation the mortality rate in patients who have a peripheral embolus has been put as high as 87% (Danzis, 1933), with the majority of the remaining 13% having to undergo amputation of the affected limb.

The ultimate prognosis, of course, is that of the causative disease.

FIG. 1.—After Pearse (1933). 296 cases.

FIG. 2.—After Danzis (1933). 119 cases.

Successful cases have been reported in which more than 24 hours have elapsed between the embolism and the operation; the present case was not admitted to hospital until 39 hours' delay had occurred, and it is very interesting to note that a limb is capable of recovering even after this period of complete anoxia, provided that a good circulation can be restored. Holst (cited by Danzis, 1933) was successful with his case after 27 hours' delay, and Girdlestone's (1935) case recovered after 24 hours. It is apparent, therefore, that operation should be undertaken even when an unduly long delay has occurred, although it must still be emphasized that the optimum time for embol-ectomy is within 4 to 6 hours of the lodgment of the embolus. This consequently means that early diagnosis is essential.

Diagnosis

The leading factor in the diagnosis of peripheral embolism is that *something sudden happens in a limb*. Often a patient will liken his illness to a “stroke,” and almost always he will be able to give the exact time of its onset. The most commonly described symptoms are pain and paralysis in the affected limb, but these are not constant. The pain may be agonizing; like a burning sensation; or merely be “pins and needles” or other

paraesthesiae. A variety of symptoms can occur; the limb may feel "cold and numb," "as heavy as lead," "as though it were gripped in a vice," etc. Together with any of these there is often loss of voluntary movement. But, whatever the symptoms, they are of sudden onset in the majority of cases, and when they occur in patients known to be suffering from mitral stenosis or other aetiological condition the diagnosis of embolism should be made and the patient sent to hospital, or other place where operative treatment can be undertaken.

Objectively the limb is cold from 1 to 2 in. below the site of lodgment of the embolus (see Fig. 3). Pallor or cyanosis may be evident, and there may be mottling or lividity below a line of demarcation. Arterial pulsation is absent distally, while pressure over the site of the embolus causes pain. Below it there may be loss of cutaneous sensation, and the deep reflexes may be absent.

The one other lesion which may really simulate embolism is an arteriospasm. This can be definitely excluded only by use of the Pachon oscillograph (Atlas, 1942), but this machine is seldom available. Graham (1937) has employed papaverine hydrochloride to relax vasospasm; but since this has no effect on embolism its value can only be in diagnosis, and it should not be used unless facilities for immediate operative treatment are at hand.

As stressed above, it is the time factor which is of the greatest importance, and this has been emphasized in all previous papers on the subject. Hamilton Bailey (1944) stresses that the occurrence of a peripheral embolus is as urgent a surgical condition as a perforated gastric ulcer.

FIG. 3.—Usual sites of lodgment of peripheral emboli (after V. H. Riddell). 382 Swedish cases reviewed by Key, 1936.

(a) Femoral A. . .	54.4%	(18)
(b) Iliac A. . .	17.2%	(2)
(c) Axillary A. . .	11.8%	{ (12)
(d) Brachial A. . .		
(e) Popliteal A. . .	11.3%	(5)
(f) Aorta . . .	4.5%	(7)
(g) Carotid A. . .	—	(1)
(h) Subclavian A. . .	—	(1)

(Figures in brackets represent the distribution of the 47 emboli recorded in Great Britain.)

Cases are very often sent to hospital too late for surgical intervention; Guthkelch (1943) mentions eight such cases seen at the Manchester Royal Infirmary. It would seem, therefore, with this and the Registrar-General's figures (see above) in mind, that many limbs—and lives—might be saved if early diagnosis and prompt surgical treatment could be instituted in these cases.

Case Report

On Jan. 2, 1945, a 43-year-old housewife awoke to find that both her legs felt numb. After some 30 minutes this wore off, and she remained comfortable until 10 a.m. on Jan. 4, when she experienced a "sudden agonizing pain in the left thigh" and noticed that her foot went "mauve." The pain continued, and by the next morning she felt as though her "thigh-bone was on fire" while her "flesh was numb like lead." On the evening of Jan. 5 she was admitted to hospital. The only relevant part of her history is the fact that she had had chorea at the age of 11, and that for some months before the present illness she had been getting more easily tired and out of breath, culminating in an attack of breathlessness and pain in the chest, which was taken to be coronary thrombosis, and for which she was being treated at home in bed, where she was when the pain in the leg started.

On examination she was found to have an advanced mitral stenosis, with a regular rapid pulse; B.P. 85/60. The left leg was white and cold from about 1 in. below the knee, with definite

mottling of the skin of the foot. The femoral pulse was palpable on both sides at the groin, while the dorsalis pedis pulsation was palpable only on the right side. The left popliteal artery was tender to pressure and felt hard. Below the knee there was no cutaneous sensation, and the deep reflexes were absent.

FIG. 4.—The embolus removed from the left popliteal artery. The first part, showing a bifurcation, was withdrawn from the distal end of the vessel.

Under local analgesia I exposed the popliteal artery, which was solid and in spasm. A small longitudinal incision was made in its lower part, and it was found to be filled with blood clot. Attempts to pick this up showed it to be friable. A fine rubber catheter, with its end cut off at an angle of 45°, was passed distally into the popliteal artery. A sucker was attached, and with the pressure at 76 cm. of water the catheter was slowly withdrawn, bringing with it the first part of the embolus, shown in Fig. 4. A flow of dark fluid blood followed. This was controlled with a tape passed around the vessel, and the above procedure was repeated in the proximal part of the popliteal artery. In this way the second portion of the embolus was delivered, but no bleeding followed. After several further unsuccessful attempts I decided to open the femoral artery, and this was done after dissecting it free in the lower end of Hunter's canal and closing the incision in the popliteal artery with a continuous suture of horsehair dipped in liquid paraffin. By means of the catheter as above the third part of the clot was removed, and this was followed by a torrential flow of bright red blood. While the flow was controlled by a tape the incision was closed, and on its release the vessel filled distally, but no pulsation was visible in the popliteal artery, which was found to be hard again. The first incision was reopened and fresh blood clot was removed and the artery resutured. This time it pulsated, and blood could be seen oozing through the needle punctures. Hot packs were applied, and within five minutes the patient volunteered the statement that her foot was "tingling." The wound was sutured and a drain was left in its lowest part. Twenty minutes later a good circulation was apparent by the rapid return of colour to the toes after blanching by digital pressure. In 24 hours the cutaneous sensation and deep reflexes had fully returned, and, apart from slight wound infection, convalescence was uneventful for three weeks. She then had started to get up and was able to walk a short distance. At this time she developed sudden abdominal pain. Apart from abdominal tenderness nothing was found on examination. There was good pulsation in both femoral arteries and also in both dorsalis pedis arteries. T. 101.2° F.; P. 98/min. regular. The possibility of a mesenteric embolism could not be excluded, and after several hours' observation without any improvement a laparotomy was carried out by a colleague, who found nothing abnormal. There was only slight pain the next day, and her convalescence continued to be uneventful. She was discharged home on Feb. 22, and is continuing her normal life so far as her cardiac condition will allow.

Treatment

As soon as peripheral embolism is diagnosed the limb should be lowered (not raised), and surrounded by ice-bags (not hot-water bottles), as the metabolism of the anoxic tissues must be reduced (Hamilton Bailey, 1944). Ideally, operative removal of the embolus should be carried out within 4 to 6 hours, but, as pointed out above, delay over this time need not preclude the possibility of recovery after embolectomy. No patient has been reported as having died owing to this operation, while the mortality rate in patients suffering from embolism of peripheral arteries has been put as high as 87% (Danzis, 1933) in those who have not been operated on.

Two other forms of treatment have been described: the first is conservative, and consists in the use of vasodilator substances (papaverine hydrochloride) and the application of alternating suction and pressure to the limb (Graham, 1937). Its value is dubious. The other method is surgical, and is arteriectomy. It was described first by Gosset *et al.* (1933); later Leriche *et al.* (1937) recorded 78 cases in which it was used, but although successful in some forms of arterial disease it was of little value in embolism.

The statistics for embolectomy, however, do show a reasonable chance of recovery in a person who is otherwise almost certain to lose a limb, and maybe his life. With this in mind it can be said that this form of treatment is the one that should be adopted in all cases of peripheral embolism, especially where the diagnosis is made early.

The recent advent of heparin (Murray and Best, 1938) may increase the chance of recovery still further, although a word of warning may be added here. For the first three days post-operatively the "specified dosage of 4,000 Toronto units" was injected intravenously daily, and at the end of this period the blood-clotting time was still only $3\frac{1}{2}$ minutes at 37°C . As its further use did not seem to be indicated the heparin was discontinued. Its effect in this case was obviously unsatisfactory, and it seems that the dosage advocated will have to be increased, and in addition very careful laboratory control must be used. There is no doubt that this drug is valuable, however, as shown by MacFarlane's (1940) case, in which he performed four separate embolectomies in the same patient with complete success; similarly it had a marked effect on the clotting time of the blood in Hamilton Bailey's (1944) case.

Summary

A brief history of the use of the operation of embolectomy is given, together with the results obtained in the past; a special note about the British cases on record is included.

The aetiology, diagnosis, and treatment of peripheral embolism are discussed.

A further case is added to the records: successful popliteal and femoral embolectomies 39 hours after the lodgment of the emboli.

I would like to express my thanks to Mr. Harold Dodd, F.R.C.S., for permission to record this case.

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Each of the above authors has described one or more cases of peripheral arterial embolectomy in Great Britain.

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The report for 1944 of the Kashmir Medical Mission of the Church Missionary Society has been received from Srinagar. The year is noted as an "absolute record" for this hospital, which, for many years under the guidance of Dr. E. F. Neve, has been regarded as one of the foremost medical missionary institutions in India. Over 48,000 visits of patients were recorded in the out-patient department and 2,707 were admitted to the wards. Though the valley of Kashmir enjoys one of the best climates in the world, the insanitary habits of the Kashmiris have not changed in the passing centuries. Outbreaks of cholera, dysentery, and typhoid persist and make possible the devastating epidemics which from time to time occur. The report is a good record of how war difficulties have been overcome—shortage of staff as also of drugs and dressings.

HIGH-COLOUR-INDEX ANAEMIA DUE TO VITAMIN C DEFICIENCY

BY

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During the spring and summer of 1943 four severe cases of adult scurvy associated with a high-colour-index anaemia of varying severity were admitted to St. Alfege's Hospital. They were all males, aged 70–80, old-age pensioners who were living alone. The diet in each case was markedly deficient in vitamin C. The most severe case ended fatally from heart failure soon after admission, but the other three responded satisfactorily to ascorbic acid. Cases 1 and 3 had hydrochloric acid present in the gastric juice in normal amounts. In the other two the gastric juice was not examined. They all received a mixed hospital diet, but were not given haematinics such as liver, iron, or vitamin B complex; yet the anaemia responded satisfactorily to saturation with ascorbic acid.

Case Histories

Case 1.—A man aged 72 was admitted on Aug. 24, 1943, with extensive bruising and purpura on the backs of his lower limbs. The spontaneous bruising had appeared three weeks previously and was becoming more extensive. He was edentulous, and his gums were unaffected. His diet had consisted almost entirely of bread, margarine, a little jam, and stewed meat, but almost no potatoes or greens. He was anaemic, and the capillary fragility (Hess) was raised. The blood count on admission was: R.B.C., 2.4 millions; Hb (Haldane), 60%; C.I., 1.25; average diameter of R.B.C., 8μ ; reticulocytes, 0.8%; platelets, 144,000 per c.mm.; W.B.C., 5,000 (polymorphs 82%, lymphocytes 10%, monocytes 8%); bleeding and clotting times normal. Hydrochloric acid was present in the gastric juice in normal amounts. He was saturated with 11.2 g. of ascorbic acid intramuscularly in 16 days. The bruising and purpura began to fade in a few days, and rapid improvement resulted. The capillary fragility test became normal in three weeks. The anaemia responded satisfactorily, as shown:

24/8/43: R.B.C., 2,400,000; Hb, 60%; C.I., 1.25; W.B.C., 5,000
9/9/43: R.B.C., 3,250,000; Hb, 74%; C.I., 1.13; W.B.C., 5,600
17/9/43: R.B.C., 4,300,000; Hb, 86%; C.I., 1.0; W.B.C., 6,000

The maximum reticulocyte count was on 1/9/43, when it was 1.6%.

Case 2.—A man aged 79 was admitted on July 2, 1943, with severe bruising and purpura, especially of his gums and the left lower limb, the latter being also swollen. The papillae of his tongue were atrophied. He was markedly anaemic, and the capillary fragility was raised. His diet had been deficient in greens and potatoes, and had consisted almost entirely of bread, margarine, cheese, and meat pies. After saturation with 9.1 g. of ascorbic acid intramuscularly in 13 days, rapid improvement resulted. The capillary fragility test became normal after one month. He refused a gastric-juice examination. The anaemia responded satisfactorily, as shown:

3/7/43: R.B.C., 2,080,000; Hb, 54%; C.I., 1.2; W.B.C., 4,500
16/7/43: R.B.C., 3,500,000; Hb, 58%; C.I., 0.83; W.B.C., 3,800
23/7/43: R.B.C., 4,100,000; Hb, 72%; C.I., 0.88; W.B.C., 4,700
15/9/43: R.B.C., 5,650,000; Hb, 108%; C.I., 0.95; W.B.C., 9,000

Case 3.—A man aged 76 was admitted on May 29, 1943. Three weeks previously he noticed spontaneous bruising of his upper and lower limbs, which became more extensive and confluent. His gums were normal (he was edentulous), but he had numerous petechiae in the mucous membrane of his mouth. His diet had consisted almost entirely of bread, margarine, and cheese. He was markedly anaemic, and the capillary fragility was raised. He was saturated with 11.2 g. of ascorbic acid intramuscularly in 12 days. After a few days of this treatment the ecchymosis and purpura began to fade and rapid improvement took place. The capillary fragility test became normal in six weeks. Hydrochloric acid was present in his gastric juice in normal amounts. The anaemia responded satisfactorily, as shown:

31/5/43: R.B.C., 1,700,000; Hb, 38%; C.I., 1.11; W.B.C., 2,500
10/6/43: R.B.C., 2,540,000; Hb, 50%; C.I., 1.10; W.B.C., 2,180
5/7/43: R.B.C., 3,100,000; Hb, 74%; C.I., 1.20; W.B.C., 3,000
14/9/43: R.B.C., 3,870,000; Hb, 84%; C.I., 1.07; W.B.C., 4,500

He died as a result of myocardial degeneration and congestive heart failure on Oct. 30, 1943.

Case 4.—A man aged 79 was admitted on May 5, 1943, with a history of three months' spontaneous bruising of his upper and lower limbs. His diet had consisted almost entirely of bread, margarine, and cheese. On admission he was found to have extensive bruising and purpura of his upper and lower limbs. His gums were spongy and bruised, and they bled easily. The capillary